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Notices of the Royal Aëronautical Society.

Election of Members.

The following members were elected at a meeting of the Council held on Tuesday, March 15th, in the various grades as shown:—

Associate Fellow.—Capt. L. C. Bygrave, A.M.I.E.E.
Students.—P. W. Dorn, H. Fraser, G. R. Irvine, T. C. Sharwood.
Member.—Major J. Gumbleton Currie.
Associate Member.—Capt. T. Oyama, I.J.N.
Foreign Member.—W. F. Eade.

Wilbur Wright Lecture.

The annual lecture in memory of the late Wilbur Wright will be delivered by Major G. I. Taylor, at the Royal Society of Arts, John Street, Adelphi, on Tuesday evening, April 12th, at 8.0 p.m. The subject will be "Scientific Methods in Aeronautics."

Safety and Economy Committee.

The Council have appointed a committee comprising Colonel O'Gorman (Chairman), Colonel Bristow, Colonel L. F. R. Fell, Captain G. de Havilland, Wing Commander J. H. A. Landon, Captain G. T. R. Hill, Major G. H. Norman, Mr. H. Ricardo, Colonel F. Searle and Mr. R. McKinnon Wood, with the following terms of reference:—To discuss the question of the type of engine and mechanical arrangements, etc., required for the safe and economical working of an aeroplane carrying mails and passengers (*a*) between London and Paris, and (*b*) over a 500-mile route. Two meetings have already been held.

Bronze Medal.

At the last Council meeting it was decided to revive the award of the Society's Bronze Medal, which has been in abeyance since the outbreak of war, and to devote it to the encouragement of the preparation of original papers by Students. Details will be announced later.

Air Ministry Conference.

Captain G. de Havilland, O.B.E., and the Secretary attended on behalf of the Society a Conference on Subsidies for Cross-Channel Aerial Transport Com-

panies, held at the Air Ministry, on Thursday, March 10th, with Lord Londonderry in the chair. Following on the conference a memorandum was forwarded calling attention to the necessity for bearing in mind the needs of designers and the construction side of the industry in order to ensure development in design.

Donations.

The Council desire gratefully to acknowledge the gift of lantern slides for the Society's loan collection from the Westland Aircraft Works, and of a copy of "Telegraphy, Aeronautics and War," by Sir Charles Bright, F.R.S.E., from the author.

Committees.

The usual monthly meetings of the Council and Committees will take place as follows:—Tuesday afternoon, April 19th, Lectures and Publications Committee, 4.0 p.m.; Candidates' Qualifications Committee, 4.30 p.m.; Council, 5.0 p.m.

Council.

As a result of the elections at the Annual General Meeting, on March 31st, the Council is now constituted as follows:—Chairman—Air Commodore H. R. M. Brooke-Popham, Vice-Chairman—Brigadier-General R. K. Bagnall-Wild, Dr. L. Bairstow, Major F. H. Bramwell, Wing Commander T. R. Cave-Browne-Cave, Sir Robert Hadfield, Captain G. de Havilland, Prof. B. Melvill Jones, Major A. R. Low, Lieut.-Colonel J. T. C. Moore-Brabazon, Lieut.-Colonel A. Ogilvie, Lieut.-Colonel M. O'Gorman, Dr. A. J. Sutton Pippard, A. V. Roe, Major-General Sir R. M. Ruck, Colonel the Master of Sempill, Major R. V. Southwell, Lieut.-Colonel H. T. Tizard, Brigadier-General J. G. Weir, Major H. E. Wimperis.

W. LOCKWOOD MARSH, *Secretary.*

ANNUAL GENERAL MEETING.

The Fifty-Sixth Annual General Meeting of the Society was held in the Society's offices, 7, Albemarle Street, London, at 5.0 p.m., on Thursday, March 31st, 1921. The Chairman, Air Commodore H. R. M. Brooke-Popham, C.B., C.M.G., D.S.O., A.F.C., presided, and the following were present :—

Council.—Brigadier-General R. K. Bagnall-Wild, Wing Commander Cave-Browne-Cave, Sir Mackenzie Chalmers, Major A. R. Low, Dr. A. J. Sutton Pippard, Colonel the Master of Sempili, Major H. E. Wimperis.

Members.—F. W. Bourne, R. M. Balston, C. F. Dendy Marshall, F. P. Walsh, G. E. Page, F. K. McClean, Sir Charles Bright, J. L. Pritchard, W. O. Manning, H. Glaser, A. P. Thurston.

Dr. Sutton Pippard, Mr. J. L. Pritchard and Mr. W. O. Manning were appointed scrutineers of the ballot for the election of Council.

The Chairman in presenting the Council's report and balance sheet said :—

There has been considerable financial improvement during the year, though there is still a deficit on the year's working of £481 3s. 4d. When compared with the similar figure of over £1,780 last year, the Council feel that a substantial advance has been made. The fact remains, however, that the balance sheet still shows a debit of £1,542 19s. 11d., which it will take some years to wipe off in the ordinary course of events. This subject is dealt with in detail in the Council's Annual Report printed in the March issue of the JOURNAL.

In spite of the exercise of economy, activities have if anything slightly increased. A good programme of lectures was delivered during the session just closed, and lectures have also been given in various provincial towns, notably a course on " Aircraft Steels and Materials " to the students of Sheffield University. I myself recently gave a lecture in Manchester which was well attended, and there is every reason to hope may lead to increased interest in that district. Efforts have been made to improve the interest of the JOURNAL, and more original articles have been printed than has been the case for some years, notably Mr. Scoble's important paper on " Cables," and the recently published articles on " The Development of German Giant Aircraft." It is hoped to arrange for further " outings " on the lines of that to the National Physical Laboratory in January. The " Safety and Economy Committee " which has been appointed is doing good work in thrashing out some of the improvements which are desirable to improve the reliability and economy of commercial machines. It is serving the useful purpose of bringing together round one table people representing various interests that do not otherwise meet, and is doing work which is not covered by such bodies as the Aeronautical Research Committee.

I wish to point out that the chief way in which members can help is by trying to get new members to join. There must be a large number of potential members who have never joined simply because they have never been approached. Every member can help by thinking over who is likely among his circle of friends. More members means an improved financial position, which will react by enabling the Society to launch out in wider fields of activity.

Technical members can also help by offering to write articles for the JOURNAL giving the results of any minor researches, etc., which they have been carrying out.

It is difficult to keep the Library up-to-date as there is no money for purchasing books, and we have to rely entirely upon publishers to send review copies, and on the kindness of those reviewing the books to return them after dealing with them. This should not be the case, and it should be possible to rely upon, at any rate, any member of the Society who writes a book presenting a copy to the Library.

It also helps the Society if technical members quote the abbreviated titles (F.R.Ae.S. and A.F.R.Ae.S.) with other distinctions when writing articles in the Press.

It is proposed to endeavour to increase the interest of students by offering the Society's bronze medal annually for the best student's paper submitted, and by arranging for students' meetings for purposes of debating among themselves. In the latter connection it is hoped shortly to be able to announce the donation of a prize annually for the best paper initiating discussion at one of these students' meetings.

The resolution was seconded by Brigadier-General Bagnall-Wild and passed unanimously.

The Council's amendments to the Rules were then proposed by Brigadier-General Bagnall-Wild, seconded by Colonel the Master of Sempill, and (subject to an amendment proposed by Mr. Dendy Marshall to Rule 25A that in place of the words " on any notepaper heading or business announcement " should be inserted " in any announcement of the nature of an advertisement ") were passed unanimously.

The rules and regulations for election to Fellowship and Associate Fellowship were proposed by Wing Commander Cave-Browne-Cave, seconded by Major H. E. Wimperis, subject to the deletion of the word " fund " after " suitable donations to the Library " on the first page. The resolution was passed *nem. con.*

The Chairman then said that he would like to express the Council's thanks to the Secretary, Colonel Lockwood Marsh. He had written the paragraph in the report himself, not by way of putting in something nice but because he really felt it, and he did think that a tremendous lot was due to the Secretary for putting the finances of the Society on a proper basis and for the way in which the Society had been run generally. He felt that the Society was to be congratulated on having got Colonel Marsh and on keeping him.

The scrutineers then presented the result of the ballot, and the following members were declared elected to serve on the Council for the two years ending March, 1923 :—

Dr. L. Bairstow, C.B.E., F.R.S., Wing Commander T. R. Cave-Browne-Cave, C.B.E., Sir Robert Hadfield, Bt., F.R.S., Captain G. de Havilland, O.B.E., A.F.C., Lieutenant-Colonel J. T. C. Moore-Brabazon, Lieutenant-Colonel A. Ogilvie, C.B.E., Lieutenant-Colonel M. O'Gorman, C.B., Colonel the Master of Sempill, A.F.C., Major R. V. Southwell, Lieutenant-Colonel H. T. Tizard, A.F.C.

The meeting concluded with a vote of thanks to the Chairman, proposed by General Bagnall-Wild, seconded by the Master of Sempill, and carried unanimously.

AIRCRAFT v. SUBMARINES.

LECTURE DELIVERED IN GLASGOW ON 15TH DECEMBER, 1920, BY

COL. L. H. STRAIN, O.B.E., D.S.C., BEFORE THE SCOTTISH BRANCH OF THE SOCIETY.

The Air Ministry, in granting me permission to deliver this lecture, have asked me to make it clear that "the statements made are based entirely on my own knowledge and the opinions expressed in no way reflect the official views." I should like to acknowledge the courtesy of the Air Ministry in giving me permission, and to say that I should be surprised if some of my opinions were in accord with the official view.

Towards the end of the war, although submarines were still doing a considerable amount of damage to shipping, the Navy was rapidly getting their measure.

Submarines were being sunk faster than the enemy could build; their submarine service had been made so hazardous that it was increasingly difficult for the enemy to man their submarines and maintain the morals of the crews during attempted operations.

This result was not achieved by any one arm of the Navy, nor by any particular invention, but was effected by the intensive use and close co-ordination of practically all the resources which the Navy could command.

British submarines stalked enemy submarines, a dangerous pastime where the hunter never knew from moment to moment that he had not become the hunted.

Mystery ships—"Q boats" they were called—cruised about inviting attack and even allowed submarines to torpedo and then shell them before showing their teeth, in order to make certain of sinking the attacking submarine.

Hunting flotillas, specially equipped, covered the danger zones listening on hydrophones for the distinctive sound of a submerged submarine's engines, and having located one, kept on the trail like a pack of beagles until they had a chance to drop depth charges effectively or until the submarine's batteries were exhausted and she had to come to the surface to fight or make a bolt for safety. Destroyers, sloops, trawlers, drifters, yachts, motor launches, even old cruisers, all played their part while there was scarcely a branch of science which the Navy did not invoke to assist in the defeat of the submarine.

Included in the organisation, and as an essential part of it, aircraft of all descriptions were used and became of steadily increasing importance as they developed in efficiency and as their proper use was better understood. It is with the part they played and the results they obtained that this paper is concerned.

At the beginning of the war senior naval officers in charge of anti-submarine operations were inclined to over-rate the value of aircraft. They realised that a seaplane travelling at 60 knots, in weather conditions which gave fair visibility, could search about 600 square miles of water in an hour, while a trawler steaming at 10 knots, having a much smaller horizon visible from her bridge, could not patrol more than 40 square miles in the same time. They had heard that from high up one could see through the water and they thought that it was only necessary to get a seaplane over a submarine for the latter to be discovered, her position indicated to the seaborne patrols, and the submarine to be sunk.

It is quite true that a seaplane can patrol 15 times as much water as a trawler, provided she stays in the air. It is also true that an aerial observer can see under the surface of the water provided the conditions are favourable. In the Mediterranean photographs have been taken of submerged submarines, but when

there is low cloud under water visibility is very small and where the sea is shallow and disturbed the water becomes muddy and therefore opaque.

The North Sea is almost an ideal field of operations for submarines; it is so shallow that in most parts a submarine can lie on the bottom without having to waste fuel and without making any noise to indicate her position. The shallow water is constantly churned up by high winds so that it is thick and cannot be seen through from the air; the visibility on the surface is usually poor and low cloud is common, so the maximum use cannot be made of aircraft.

At the beginning of the war there were no trained aerial observers. There were only about 20 seaplanes around the British coasts which were in any degree fit for active service, and these had extremely unreliable engines. As an example, the seaplanes at Dundee and Granton had 160 h.p. Gnome engines which broke down completely on an average every 2 hours 44 minutes, yet the machines had to be sent on two to three patrols.

Small wonder that aircraft proved a bitter disappointment to senior naval officers. Not only did they have no tangible success, but they were constantly breaking down at sea, pilots and observers were lost, and destroyers had to be diverted from their regular duty or taken from their hard earned rest to search for missing machines and ran the risk of being torpedoed while picking up a seaplane or while towing her home at slow speed.

The inevitable result was that many senior naval officers proclaimed aircraft as being more bother than they were worth and ceased to ask for their assistance. Consequently the development of sea-going aircraft was retarded and the efforts of the R.N.A.S. were largely devoted to performing "stunts" on the Western Front in competition with the R.F.C., or in raids on the German coast from seaplane carriers; gallant work, but without much material effect on the course of the war.

For a time development in seaplane construction stood still, but slow progress was made in other branches of aviation. Early in 1915 the kite balloon was successfully adapted for work at sea while being towed by a ship. Shortly afterwards the submarine searching airship or "blimp," composed of an old-fashioned aeroplane fuselage carrying a pilot and observer suspended from a small envelope filled with hydrogen, made its appearance.

These, with such seaplanes as were not required for the seaplane carrying ships or were unsuitable for them, were scattered round the coast and did a lot of haphazard work with, however, little effect. Although experience was gained and gradual improvement was attained, it was not until the War Staff at the Admiralty was reorganised by Lord Jellicoe that there was any marked development in the use of aircraft for submarine hunting.

One department of the War Staff was devoted exclusively to anti-submarine measures and was put under the charge of Admiral Duff, with very wide discretionary powers. Parts of the organisation were an anti-submarine division anxious to explore and co-ordinate every conceivable means of defeating the submarine, and a section of the Air Division of the War Staff devoted solely to anti-submarine warfare and working in close co-operation with the anti-submarine division.

An organisation embracing all areas of submarine activity, a plan of operations and a programme of development were settled. The provision of personnel and their special training, the selection of suitable types of aircraft and their supply in sufficient quantities, the equipment and armament of aircraft for anti-submarine work, the distribution of intelligence, arrangements for signalling and co-operation with surface-borne craft were all decided on.

Practically a new service came into being which had no inconsiderable effect in countering the activities of enemy submarines.

Owing to the immense importance attached by the War Cabinet to the bombing of Berlin and their direct orders that the provision of anti-submarine aircraft should be subordinated to the equipment of a large independent air force for that purpose, the anti-submarine organisation and programme of development had not nearly attained their full growth by the time the Armistice was concluded.

Much, however, had been done and its effect was abundantly clear on the course of the enemy's submarine campaign.

There are three principal ways in which aircraft can be used effectively against submarines.

1. They can attack the submarine bases, sinking submarines in port, destroying their torpedo and other stores, wrecking the machinery and appliances for repairing and refitting the submarines, and killing personnel.

   Unlike work at sea, where one may patrol for months without sighting a submarine to attack, there is always a valuable objective in the base itself and persistent attacks are bound to have a considerable effect.

2. Aircraft can patrol very large areas at sea, attacking submarines when found, directing sea-borne patrols to the place and compelling submarines to remain submerged, when their effective range is greatly reduced.

3. Aircraft can be used defensively to escort and protect shipping and locate minefields.

Let us deal with these three matters in turn and examine what success was attained and some of the reasons for failures.

1. Attacks on Submarine Bases.

It is generally known that for operations in the southern part of the North Sea the Germans had submarine bases at Ostend, Zeebrugge and Bruges. A large naval air station was maintained at Dunkirk principally for the purpose of attacking these bases.

In order to give some idea of the intensity and persistence of these attacks I have collected the figures of bombs dropped in these submarine bases between April and September, 1918.

In all 10,432 bombs were dropped, weighing 847,904lbs. or just on 334 tons of bombs. On the average 57 bombs were dropped on them every day or night.

The figures are:—

	Bombs.	lbs.
Zeebrugge	2,254	189,871
Ostend	2,841	184,000
Bruges	4,284	378,032
Canal objectives	833	47,339
Submarines in harbour or entering or leaving	220	48,662
	10,432	847,904

The bombs varied in weight from an enormous thing weighing 1,600lbs. down to little 16lb. and 40lb. incendiary bombs. Think what this meant to the people and objectives below!

Think also of the arduous work required from those in the air and remember that the anti-aircraft fire was probably more intense than anywhere else on the Western Front and that hosts of enemy fighting machines were always guarding these objectives.

Bombing by way of counter-attack was also common. For instance, on one night Dunkirk Naval Air Station had 300 bombs dropped on it. Not a soporific for tired personnel.

Many a good man was lost to the Naval Air Service there, but his work was not thrown away; it exercised a material effect on the enemy submarine campaign.

In order to protect their submarines from bombs the Germans built immense concrete shelters, which in itself shows the straits they were in to maintain their submarine campaign in the southern part of the North Sea. Even these shelters were insufficient to protect the submarines, which could be caught entering or leaving, and even when they were under cover a direct hit from a large bomb caused more than one such shelter to collapse.

After the blocking of Zeebrugge and Ostend by "Vindictive" and the other ships on St. George's Day and the enemy's experience of some months of intensive bombing from the air, bombardment from the sea and mining off these bases, they were abandoned. The enemy's North Sea submarine campaign was carried on afterwards from the German bases in the Heligoland Bight, which were much further from their objectives.

These other enemy submarine bases in the Heligoland Bight and those in the Adriatic and at Constantinople were too far away for them to be attacked with that regular persistence which is necessary to secure moral effect or real material damage. Occasional raids were made which had no substantial effect except in containing a large number of anti-aircraft guns which would have been more troublesome elsewhere.

2. Attack on Submarines at Sea.

The old cookery book's recipe for hare soup, which began "first catch your hare," applies equally to submarine hunting. The submarine must be found before it can be destroyed, neither of which is easy.

To have the best chance there must be specially trained officers in suitable aircraft working in close co-operation with surface and being supplied with the latest intelligence regarding the movements of enemy submarines.

Training.

The aircraft may be the most perfect in the world, but it is in vain to expect results unless the observers in the machines are trained to distinguish enemy submarines from our own, what a periscope looks like, and from what height it can be seen, the tactics employed by enemy submarine commanders, how they attack and how they avoid attack; the performance of various types of submarine, what speed they are capable of on the surface and submerged, their endurance while under way submerged, how long it takes them to dive, what depth they can dive to, how long they can lie on the bottom and what sort of roosting ground they will choose. Having got in touch with a submarine the observer requires to be able to drop bombs accurately (he seldom gets a second chance), to know how far ahead to aim if the submarine is at periscope depth, how much further ahead if the submarine is running deep, when machine-gun fire may be of use, how to plot the position of the submarine accurately and how to communicate the information to surface hunting craft, to convoys and to his base, all of which requires careful and lengthy training; much more training than to become an efficient pilot. In the early days of the war observers were quite untrained and only picked up useful knowledge from their own keenness to learn and their association with naval officers of submarines, signal, navigation and other branches.

Latterly a special submarine hunting school was started where, in addition to learning all the subjects outlined above, observers had opportunities of prac-

tising with our own submarines and surface hunting craft, going to sea with them, and, what was equally important, officers of the submarine and submarine hunting services were taken up in aircraft so that they could appreciate the advantages and the difficulties of the Air Service.

It is noteworthy that some four months after the British school was started Germany woke up to the necessity of such a school and started a similar one.

Suitable Aircraft.

The first essential of aircraft for anti-submarine duties is that they should have a perfect view ahead and underneath the machine in order that the observer should have the best chance of sighting and bombing a submarine before she sees the aircraft and dives. Aircraft of the " pusher " or " twin tractor " type have this quality and obtained much better results than the usual tractor type, where the observer's view ahead is obstructed by the engine and his eye is tired by the propeller flicker.

The machine should be as noiseless as possible. The noise of aero engines is very insistent and aircraft are as a rule discovered by sound long before they are seen, particularly in conditions of low visibility or if they are coming from the sunny side. Silence, which is almost as important for land bombing machines, was ignored until late in the war, but at the request of the anti-submarine service experiments were undertaken and some success was obtained, but the complete silencing of the engine without material loss of power and the silencing of the propeller has not yet been solved. When it is the value of aircraft, not only for anti-submarine work but for practically all war service, will be more than doubled.

Great speed is not necessary for anti-submarine work, but long endurance is essential.

Machines should be capable of alighting on and rising from a fairly rough sea. This is necessary for several reasons:—

1. Hydrophones are instruments like telephone receivers, which are very sensitive to underwater noises. Some types can pick up the sound of propellers even 15 miles away. Seaplanes can be fitted with hydrophones so that they can alight, listen for the distinctive sound of a submerged submarine and indicate its position. In this they have a great advantage over surface craft as submarines have hydrophones on which they can hear the propellers of surface craft and in shallow water like the North Sea can lie quietly on the bottom until the absence of sound assures them that it is safe to come to the surface.

The sound of an aero propeller, however, even from a seaplane which has alighted close to the submarine, cannot be heard on her hydrophones, so seaplanes able to alight and use hydrophones can hunt a submarine when she does not know she is being hunted, which surface craft cannot do.

A certain measure of success was obtained in the Ægean with hydrophones used from seaplanes. Later in the war flying boats used round the British coast were being fitted with them, but as these boats had difficulty in rising from anything but calm water with a war load the occasions on which they could be used were few.

Consider the advantage of hydrophones fitted to seaplanes which can alight on and get off a fairly rough sea. A submarine is located in a particular area by night or day. A flight of four such seaplanes is sent out. Three spread themselves out at extreme hydrophone range, say five miles apart, and alight to work hydrophones, the fourth remaining in the air to attack as directed and to work wireless. Nothing is heard, so the three rise, fly five miles further on and again sit down to listen. In an hour they can make a hydrophone search of an area of 400 square miles without the submarine knowing she is hunted unless she comes

up and uses her periscope, when the machine in the air has the chance of sighting and bombing her.

If the machines on the water hear a submarine the three should each be able to get a bearing of the sound and plot the position of the submarine with sufficient accuracy to taxy over the spot and depth-charge it.

2. The capacity of alighting at sea is also valuable for the sense of security it gives to the personnel. Flying aeroplanes out of sight of land at sea, day and night out, is very trying even to the best personnel. Engine failure means probably drowning, certainly an unpleasant cold bath, which after some days of routine patrols creep into the back of their minds and they cannot concentrate their entire attention on examining the sea as they can if they feel secure. It is noticeable that submarines were sighted much oftener per 1,000 miles flown by seaplanes than by aeroplanes.

3. If caught by fog a seaplane can come down and wait until it clears while an aeroplane has to make a hazardous return to land.

Submarine hunting aircraft should also be able to carry a heavy load of bombs.

Where work has to be done within flying distance of the enemy coast these machines or escorting machines must have good fighting qualities.

We lost many valuable machines and men through the German seaplanes being far superior to ours in these respects. The German seaplanes were so seaworthy that they could alight outside the North Hinder lightship, exposed to the whole force of the North Sea, and await our patrols, then rise and with their greater speed and power of manœuvre fly round our machines, attacking as they chose and breaking off the engagement at will.

One instance of such a fight deserves to be told. On 18th July, 1918, two Short seaplanes with two Camel aeroplanes as escort left Westgate on anti-submarine patrol. They were attacked by seven enemy seaplanes, six of which were small fighters capable of outflying the Camel aeroplanes. One of the enemy seaplanes was shot down. The large enemy seaplane engaged in a duel with one of the Shorts. Each winged the other and both came down on the water. They "taxied" towards one another, firing as they went. The last seen of either machine was both machines on fire close to one another still firing their machine-guns. R.I.P. The other Short seaplane was also lost.

These desiderata indicate that the seaplane, or better still the amphibion which can alight on or rise from either water or land, is the most suitable for anti-submarine work.

We never even approached this ideal. Until the end of the war the great bulk of the work was done by the old-fashioned Short seaplane which had a poor view ahead and below, was noisy, could not carry a great weight in bombs and was not very reliable.

These were assisted by the little airships—"blimps"—which were very conspicuous and so slow that in the Mediterranean the more dashing of the submarine commanders used to come to the surface up wind of the "blimp," steam into the wind so that the overtaking speed of the airship was small, and have target practice with their gun at the airship, to the discomfiture of the latter.

The enemy submarine commanders got to know and appreciate the tactical qualities of these aircraft and for the time evaded them.

Then the so-called "Large America" flying boat, designed by Wing-Commander Porte of the British Naval Air Service, made its appearance. This type had twin engines which gave the observer a perfect view ahead, could carry

heavier bombs than Short seaplanes and, having a greater endurance, could venture further to sea.

A notable example of the seaworthiness of these seaplanes was the case of a Large America which came down in very bad weather near Heligoland. The weather was too bad for the Harwich light forces to search for them and the machine was given up as lost. Her crew, however, being seamen, had rigged a sea anchor to which they rode for three days, drifting across the North Sea, when the storms having abated, they got their engines going and "taxied" into harbour under their own power.

As is usually the case in modern warfare when a new invention is sprung on the enemy, the flying boat enjoyed a considerable success. The periscopes of enemy submarines could not at the time see more than 30° from the horizontal, they were thick and when travelling at 3 or 4 knots made a very noticeable "feather" in the water. Before the enemy realised their disadvantage the flying boats had sunk six enemy submarines and damaged others.

Success in attack, where some new invention is responsible, is always met by improvement in defence. The periscopes of enemy submarines were made thinner, as thin as a lusty walking stick, and did not give as pronounced a "feather." An "altiscope," which could examine the sky before a submarine came to the surface, was fitted in each boat, and submarine commanders with their new respect for the powers of aircraft became much more wary when within reach of air stations.

The areas where submarine activity became most pronounced by day were a long distance from air stations and their work in the immediate neighbourhood of air stations was carried on mostly by night.

To meet the first it was necessary to improvise mobile bases for aircraft. The first experiment was carried out in the Ægean, where the tide is small and where places suitable for advanced bases are common. Machines flew to these places, followed by a trawler fitted with a gun to protect them and carrying stores and air ratings. Machines—seaplanes—were filled up with fuel and operated from the advanced bases and were able to patrol areas where their presence was unsuspected, so worrying submarines into finding spheres of operations still further afield.

In British coastal waters the same practice was instituted, a ship, "Aviator," was adapted as mother ship and mobile base to seaplanes working off the coast of Ireland, moorings for aircraft were laid down in sheltered spots and in this way the range of aircraft was largely increased.

To counter submarines operating at night aircraft seemed of very little use; there were only two ways in which they could be of much assistance, firstly by fitting them with hydrophones so that they could listen for submarines, and secondly, fitting them with parachute flares which would descend slowly, lighting up a large radius of water and compel submarines within their radius to submerge, so preventing their getting into position to attack shipping or lay mines and, still more important, preventing them recharging their batteries and so limiting their sphere of activity.

Statistics compiled by the Intelligence Division showed that the average length of cruise of submarines operating on the east coast of Britain was reduced from seven to five days, a result which they attributed very largely to the intensive use of aircraft keeping submarines from the surface and so exhausting their battery power.

Armament.

To attack a submarine successfully not only requires special armament but also necessitates special training. Consider the problem:—

A submarine may be caught on the surface or it may have had warning and submerge before the aircraft is over her in a position for bombing.

If she is on the surface, bombs which are fused to detonate below the surface may not injure her even if they make direct hits. There were at least two cases where bombs with time fuses made direct hits on submarines on the surface, splintered without detonating and did little damage. A modern submarine is a strongly built affair with two skins, one of them thick, and to injure her on the surface either small armour-piercing bombs are required or small high velocity shell from a quick-firing gun, either of which will pierce both skins and prevent her submerging. With older type submarines, or the small German mine-layers, which have only one skin, machine-gun fire may be effective and an observer must be able to recognise types of submarines and deal with them accordingly.

One example is instructive. An old British submarine, C25, had been doing coastal patrol off Harwich and was coming off duty when a flight of aircraft was observed coming towards her. They were thought to be British aircraft and no special precautions were taken. Suddenly bombs began dropping all around C25 without doing material damage, then machine-gun fire was opened from the aircraft, which were German, and some of the bullets pierced the skin of the submarine. She had started to submerge but had to come up again as water was pouring in and causing a poisonous gas from the electric batteries. The seaplanes had expended their bombs and alighted around C25. The submarine's captain and one rating went up to the conning tower with their machine-gun. They were killed and the machine-gun lost overboard.

The sub-lieutenant tried to ram the seaplanes but his rudder was jammed, so both sides lay impotent, unable to damage the other.

At last the seaplanes rose and flew back to their base for more bombs.

An E class submarine, which had seen the end of the action, came up and took C25 in tow. The seaplanes returned and the E boat quietly submerged and lay on the bottom at the end of her tow line while the second abortive attack was delivered, then rose unsuspected by the seaplanes and finished towing C25 to harbour, the survivors of C25's crew having flatly refused to leave their ship although they knew the second attack was coming and that they could do nothing in reply.

If, however, the submarine has submerged before aircraft are in position to bomb her the problem is more complicated. She may have submerged only to periscope depth, about 26 feet, or she may go to her maximum diving depth, about 180 feet. A bomb fused for the one depth will not injure the submarine at the other, while one fused as a compromise between the two depths will injure a submarine at neither.

The observer has to make up his mind immediately. If there are deep minefields in the neighbourhood, known to the enemy, it is unlikely that he will risk going deep. A knowledge of the soundings in the vicinity will be another guide. Local knowledge and quickness of perception are his chief resources. If the machine can carry sufficient weight, bombs dropped to straddle both depths will give much more chance of damaging the submarine if dropped far enough ahead.

How far ahead to drop the bombs also requires expert knowledge and practice. The observer may only see a thin streak of oil or a tiny line of air bubbles. Air comes to the surface much faster than oil and both rise more slowly than one would suppose. The calculations which were made early in the war proved to be wrong and many a submarine must have got away uninjured through bombs being dropped too far astern to do damage. But even if the observer knows how far to aim ahead for particular depths at which the submarine may be he still has to make up his mind and make the necessary allowance for whether

the submarine is at the periscope depth or running deep; whether she is still on her dive, when the advancing speed will be small, or whether she has taken up her depth; whether she is likely to hold her course or turn to port or starboard.

The only satisfactory method is, like the use of a shot gun at a snipe, to strew the whole area with bombs fused to detonate at all depths, for which, if aircraft are to deal with the submarine unaided, patrols should be undertaken by a flight of weight-carrying aircraft, working together, rather than by single machines. As an illustration:—

On 24th July, 1917, five large flying boats were patrolling in the vicinity of the North Hinder lightship. One of them sighted a submarine just submerging and turned to attack it. The other four followed her and all dropped their bombs in a salvo around where the submarine had dived. That was the end of the German submarine U.C.1. One seaplane might have sunk her, but five seaplanes dropping ten 230lb. bombs together made a practical certainty of it.

More certain results can be obtained from close co-operation between aircraft and surface hunting craft, which can carry a much greater weight of explosives than is at present possible in aircraft. The subject of co-operation is itself a large one which I do not propose to deal with except to say that the three essentials are:—

A knowledge of the powers and deficiencies of the arm with which one is co-operating.

Adequate signalling between the two arms and perfect trust in the other arm knowing and carrying out its own job.

Organisation.

In other respects rapid improvement was made in the last two years of the war.

With experience the intelligence system had been developed and the deductions of the Naval Intelligence Division made more readily accessible to those in charge of operations.

From logs and other papers captured in enemy submarines a great deal had been learned about the personnel of their submarine service, their tactics, the equipment and performance of their various types of submarine.

The tracking department could tell with considerable accuracy not only how many submarines were operating around the British coasts, but also which individual submarines were at sea, who were their commanding officers, how long they had been at sea and when they would probably require to return to port.

Often, too, the tracking department could give the exact position of a submarine and forecast her probable course.

With this information at the disposal of those in charge of operations, submarine hunting was rapidly becoming less of the needle in the haystack variety, and the work of surface craft, British submarines and aircraft could be co-ordinated to harry enemy submarines increasingly.

Defence Work.

In addition to their work in bombing submarine bases and hunting submarines at sea, aircraft were largely used latterly for defence against attack by submarines.

This took the form of escorting convoys and single ships, patrolling swept channels and convoy routes to prevent submarines coming to the surface to examine their targets and get into position to attack; in locating minefields laid by the submarines and destroying mines which had come to the surface.

Escort Work.

The obvious success in escorting surface craft with aircraft caused aircraft to be devoted much more to this duty towards the end of the war, and in order that aeroplanes also should be used the coastal convoy routes were brought more inshore.

The figures for 1918 are:—4,869 escort flights were undertaken by seaplanes and aeroplanes. Only two vessels were attacked while under escort and on one of these occasions the aerial observer saw the track of the torpedo starting and was able to signal and warn the ship aimed at in time for her to alter course and avoid the torpedo. 2,141 escort flights were made by airships, only one vessel being attacked while being so escorted and on that occasion the airship was five miles away from the ship when she was attacked. 131 escorts were made with kite balloons towed from surface escorting craft during which three vessels were attacked. On two of these occasions the approach of the torpedo was observed from the kite balloon and the third attack was made at dawn when visibility was very bad.

In comparing these figures it must be remembered that the length of escort undertaken by airships was about three times that of seaplanes and aeroplanes, while kite balloon escorts average several days duration.

The success of aerial escort is not so much due to aircraft being able to prevent attack as to the fact that the track of a torpedo is very apparent from the air, and a submarine commander knows that as soon as he makes an attack the position where the torpedo track began will be bombed by the aircraft and the water-borne escorts will be directed to the place to depth charge it heavily. This changed submarine attacks on defenceless merchantmen from being a safe pastime for the Hun into a dangerous operation which he was not so anxious to undertake.

For this work airships were in many respects better than seaplanes or aeroplanes, they have a longer endurance and can cruise round a convoy at slower speed, but if an attack is delivered an airship takes longer to get over the torpedo track and bomb it, particularly if the attack has been delivered up wind of the airship.

There is only one instance of a submarine having been sunk by an airship; that was the Scotch built airship R.29, which was not intended for unit submarine work, but which found and bombed U.B.115 on 29th September, 1918, and then directed two torpedo boat destroyers and three trawlers over the spot. They finished off the submarine with depth charges.

There is also only one recorded case of a submarine having been seriously damaged by an airship.

This lack of success is not to be wondered at when one considers what obvious features of a seascape airships are, even when seen through a periscope, and how long it takes an airship to get over the position where a submarine has submerged. They were very useful scarecrows when acting as escorts, but it is doubtful whether their work would not have been as well done by kite balloons at infinitely less cost in personnel and material, freeing many men and much material for the heavier-than-air branches.

In the weather when airships usually patrol even a periscope is fairly conspicuous and submarines do not like to operate.

For example, take the aircraft operating on the north-east coast of England from 1st July to 30th September, 1918. There were 58 days on which no flying was done by airships. On these days 40 attacks were made by submarines on British shipping and 29 sightings, mostly followed by attack, were made by seaplanes and aeroplanes on enemy submarines. Airships in that area only sighted submarines on four occasions during the three months.

Results.

The defensive value of aircraft in preventing attack on shipping, locating minefields and diverting traffic from danger zones cannot be assessed in figures. No one can hazard a guess at the numbers of ships saved or the tonnage of supplies brought safely to Britain because of the work of aircraft. It must be very large.

Other results are known and give some indication of the value of aircraft in anti-submarine warfare.

In 1917 submarines were sighted from aircraft on 169 occasions, of which they were attacked on 106.

In the nine months of 1918 submarines were sighted 192 times, of which 130 resulted in attack.

It must be remembered that in 1918 aircraft were much more devoted to escort work which accounts for the greater mileage flown for every submarine sighted.

As an indication of the expansion of the work, the distance flown by aircraft on submarine patrol in home waters in 1917 was 1,526,475 miles, while in the nine months of 1918 this had increased to 4,801,347 miles, nearly three times as much.

Prior to 1917 only one submarine was known to have been seriously damaged by aircraft. That was in 1915.

In 1917 seven were sunk and 15 seriously damaged by aircraft. Six of the submarines sunk, viz. :—

U.C. 36 on 20th May,
U.C. 1 on 24th July,
U.B. 20 on 29th July,
U.B. 32 on 18th August,
U.C. 72 on 22nd September, and
U.C. 6 on 28th September

were sunk by large America seaplanes unaided.

One submarine, U69, was sighted from a kite balloon towed by "Patriot," which was directed where to drop her depth charges and sank the submarine.

In 1918 four submarines were sunk, six seriously and 20 slightly damaged by aircraft. All the submarines sunk were finished off in co-operation with surface craft. They were :—

U.C. 49 on 31st May,
U.C. 70 on 28th August,

both of which were found by fairly fast aeroplanes with a good view ahead.

U.B. 83 was sighted from "Ophelia's" kite balloon which directed her over the spot, and U.B. 115 was sighted from airship R.29 on 29th September and sunk by her in co-operation with destroyers and trawlers.

Everyone engaged in the anti-submarine campaign will always regret that the ultimate test of their organisation was not carried through. In October, 1918, the tracking department of the Intelligence Division traced a hiving homewards of enemy submarines and their concentration in the North Sea off the entrance to the Firth of Forth.

From this and other indications it was apparent that the concentration of submarines was to play an important part in Germany's last gamble, a general naval action.

The British anti-submarine organisation was put on a mobile basis and among other arms aircraft were concentrated to meet the enemy submarines.

Unfortunately the enemy fleet refused to put to sea and the last test of whether we could rely on ourselves to defeat the submarines or whether, as politicians want, we should ask a League of Nations to prohibit their use in future wars and so confess our impotence remains undecided, but I believe firmly that so long as the Navy and the new Air Force work whole-heartedly together and are given enough money for practice flights and experiment, we need not fear the submarine in future campaigns.

PROCEEDINGS.

SEVENTH MEETING, 56th SESSION.

The Seventh Meeting of the Fifty-Sixth Session of the Royal Aëronautical Society took place in the hall of the Royal Society of Arts, London, on Thursday, January 20th, 1921, the Right Hon. Lord Weir presiding.

The CHAIRMAN, in introducing the lecturer, said about 27 years ago Lord Montagu adopted a young and very delicate child. On its upbringing and its introduction into the British industrial world he devoted a large part of his time and a very considerable measure of his wonderful energy and enthusiasm and played a very prominent part in fostering the recognition of the child as a useful factor in industry and obtaining liberty for the infant to run about our roads and highways. He (the Chairman) did not think he neglected any opportunity of reading papers before the different societies, forecasting the wonderful manhood which would be achieved by the community if it would support and encourage the industry. To-day he had the proud satisfaction of looking at his one time infant prodigy. By that prodigy he (the Chairman) meant the petrol-driven passenger and commercial vehicle. He was responsible for an entire revolution in our system of transport, which was the basis of a strong and healthy British industry. Since the beginning of aviation Lord Montagu had adopted it as another child, and one with infinite possibilities. He had been one of the strongest supporters and most active workers in the development of aviation. He was now going to give them the pleasure of hearing his views on the more commercial aspect of the different forms of transport. Lord Montagu was a founder of the Society and had always been one of its strongest supporters. To-night it extended to him a very hearty welcome.

Lord MONTAGU OF BEAULIEU then delivered the following lecture:—

A COMPARISON OF THE COST OF TRANSPORT AND TON-MILES BY LAND, SEA, AND AIR.

All methods of transport must be judged by their cost of operation and the revenue they produce, and the comparison, therefore, of the cost of ton-miles provides a useful but not the only basis from which conclusions can be drawn as to the efficiency and utility of such services. Vehicle, train, ship, or air miles and their cost must also be considered as well as ton-miles, and above all the factors of speed and the completeness of the service from the point of view of the user must be taken into account.

We have seen during the last few years attempts made to bolster up certain methods of transport on the ground that they are beneficial as a whole to the community, to special trades, or to the welfare of particular places or classes. But sooner or later the practice of subsidising any kind of transport out of taxes or rates, or out of the proceeds of other allied concerns, will have to be recognised as unsound, though there are exceptional cases where one service is naturally complementary to another kind of service, and in the end the methods of transport that will survive will be those that can stand upon their own bases. It must be remembered, however, that during the early stages of any new kind of business or of transport, such as transport by air, it may be advisable from a national

point of view to give definite help in order that it may survive its initial difficulties. But I desire to impress upon my audience at the outset that though help may be given for a definite purpose or for a stated time in the preliminary stages, in the case of air transport it cannot, like other means of transport, survive eventually unless it earns sufficient revenue to pay for the cost of operation plus a reasonable interest on the capital involved.

The actual cost of transport does not matter, or if one form of transport is more costly than another, if the particular type has some inherent qualities which appeal to the public who use it and will pay enough for its use. To take examples, it may be said that two such qualities are (*a*) high speed such as air transport can provide, and (*b*) comfort and convenience in trains or ships for which passengers will pay beyond the mere payment for conveyance. To deal with the first of these, speed much in excess of the normal or most economical speed always costs a good deal more whether by land, sea or air. From the scientific point of view this must be so, because increased speed by land, sea or air involves more resistance to travelling through the medium such as air or water as well as greater friction in the propelling and power-transmitting machinery, demanding therefore more expenditure of power. In addition, in some cases increased speed means the employment of more skilled and more highly paid labour, though not necessarily of a greater amount of labour. Speed, let us remember, is a comparative and not an exact term and what is called speed varies much in rate of miles per hour in each element and in each kind of transport. The fastest sea speed, for instance, is a speed considered moderate on land, while the fastest land speed to-day is slow compared with the latest achievements of the airplane.

In the case of air transport to-day, high speed compared with other means of transport is the greatest asset, and for certain goods and passengers this kind of high speed will always be in demand. Moreover, the longer the journey the greater the advantage conferred by high speed. Nor do ordinary economic conditions, as expressed in formulas such as the cost of ton-miles, apply in many cases. The fastest trains, motor cars and liners are largely used because they save time, and time to many persons means the capacity of making or saving money. In other words, the saving of time in transit is willingly paid for by a section of the public, and the minutes, hours, or days saved by high speed can be sold in the open market at varying prices, in addition to the right of transportation between the points of departure and arrival. For instance, the route from England to India direct by airship is about 3,600 miles, and at an average speed of 50 miles an hour this journey would take about 72 hours or three days, while the fastest journey by the existing overland and mail ship route to-day takes 15 to 16 days. Such an airship service, which as a matter of fact is quite a practical proposition to-day from a mechanical and aerial point of view, would save about 12 days over any existing route to India, and these 12 days would be worth to certain passengers so much for money making, important political work, urgent private affairs, or other special reasons. In the case of fast transport, therefore, particularly in air transport, the public authority or the company providing the transport is really selling not only the right to the individual to be transported from A to B, but a certain saving of time in comparison with the next most rapid means of conveyance. This is the real reason why high speed is commercially valuable and will always be valuable. Also, in addition to this, there is always the common human characteristic of impatience and intolerance of slowness, and the desire to get to a destination quickly, which is always manifest in all energetic and alert nations and individuals. On the other hand, delay and slowness is immaterial to certain persons and races either in the case of those whose mental development as a rule is not very high, or whose habits and circumstances are such as to make the passing of time an immaterial factor in their lives. This latter reason is exemplified in India where the majority of Indians prefer to travel by slow trains and slow road conveyance, because they are never in a hurry. In

addition the traveller by train appreciates a comparatively comfortable seat and protection from the sun or rain for the longest time possible and express trains arrive too soon for such individuals. Flying is admittedly the fastest method of transport, and it is difficult for the human mind to think of any faster method of transport. Eventually, therefore, Governments or commercial companies should be able to sell in future transportation by air chiefly because of the saving of time which great speed is able to achieve.

I have devoted these opening sentences to a brief discussion of the question and value of speed, because in considering any kind of transport statistics, especially ton-mile statistics, it is not only the cost per mile or per ton or per passenger which must be considered in comparing the different methods of transportation, but as I have already pointed out, the value of speed as well if a useful comparison is to be made out.

We will now consider first of all the cost of ton-miles by land transport. Any consideration of horse transport I will omit for it is dwindling fast and forms less than 10 per cent. of the passenger and freight traffic of our streets and roads to-day. It is admittedly, however, for certain purposes and for short distances a cheap form of transport. Also I will not touch on the question of tramways as with very few exceptions they convey passengers only and only operate for short distances. They are also becoming less important in comparison with other forms of transport. But in nearly all forms of land transport the cost of labour is now such a large proportion of the total cost of operation that those methods of transport that employ the least labour are those which now and in the future are likely to be the most popular and the cheapest. The expenditure of more mechanical power in the conveyance of passengers or goods is of comparatively little importance to-day compared with the extra cost of the labour bill, and an increasing tendency, therefore, is seen in every direction in regard to ships, railways and mechanical road vehicles to replace human labour by automatic devices and mechanical means. On ships the substitution of oil fuel for coal, also making a ship independent of coal strikes, is one of the manifestations of this tendency, while on railways the employment of automatic signalling, larger locomotives, auto-transporters of every form, and escalators for passengers are all methods of reducing the cost of labour needed per ton or per passenger moved.

As regards road transport, the cost of labour per ton-mile is high and the trailer is coming more and more into favour as economical of power and as saving labour. Constant strikes and the raising of wages time after time have also disorganised the economic conditions of various forms of transport, and in some cases made them so costly that the economic limit has been reached and bankruptcy stares some concerns in the face. The loss on the tramway systems of this country reached a figure of over three millions sterling last year. The public refuse to pay more and the receipts are in some cases less than at the lower fares. Such a condition of affairs cannot last long. Railways in general also are by no means solvent concerns in the majority of cases.

As to the air, which we are considering specially to-day, aviation has some undeniably inherent advantages. There is, for instance, no permanent way to keep in order, and the necessity for the employment of a large amount of labour exists chiefly in the case of the dirigible. No practical mechanical means has yet been generally adopted for releasing or mooring an airship without the help of a considerable number of men. But developments are proceeding which will reduce certainly a proportion of the expense of manual labour.

I will now come to the actual cost of ton-miles so far as I have been able to obtain statistics, and in putting before you the following figures I must thank various individuals and firms for the information they have given me.

To deal with road transport first of all. The cost of mechanically propelled vehicles should be based on an estimate of a maximum of 250 out of the 300

working days per annum, that is about two-thirds of the total days of the year. Taking the commonest type in this category, the petrol operated vehicle, carrying 3 to 3½ tons useful load, I find on collating many statistics that the average cost of operating these, on the basis of a run of about 40 miles a day, is about 2s. per vehicle mile, or a cost of about 8d. per ton-mile. This charge, it must be remembered, generally includes the wages of one or two men, who help to load and unload, in addition to the actual conveyance of the load from door to door, and not only from station to station as in the case of the railway or from port to port in the case of ships. The operation of a 3-ton steam vehicle on the same mileage basis I put at about the same ton-mile cost, namely, 8d., but in this case the saving in fuel cost is balanced by high mechanical repairs owing to the existence of the boiler, furnace, and water supply system. The cost of the smaller 30cwt. van can be put at about 1s. 6d. a mile or about 1s. a ton-mile. This sort of vehicle is chiefly used for parcel delivery or light goods. When large fleets of motor lorries or vans are used the fixed and overhead charges are of course less averaged over a considerable number of vehicles, and again, liquid fuel is bought cheaper in larger quantities, and repairs done more cheaply at home in most cases. As to the cost of the electrically propelled vehicle, the simplicity and handiness of these vehicles, added to their cheapness in operation, have made them very popular of late. Taking electric current at the high figure of 1½d. a unit or about double the cost in large quantities before the war, the expense of each vehicle mile works out with a 3-ton lorry at about 1s., or about 4d. a ton-mile. The limited radius of action—about 50 miles on one charge—is an inherent drawback for long distance work. But for collection and distribution in towns no transport is cheaper than the electric vehicle.

Recently I was able to investigate the figures of a certain County Council showing the cost of operating 16 mechanical vehicles used for road repair—three petrol and 13 steam operated. The ton mileage in this case worked out at a cost of 14.083d. This cost is unusually high and will be reduced no doubt before long. But such work as was done was somewhat intermittent and the vehicles necessarily stood idle for considerable periods and when on the road covered as a rule only short journeys.

In this calculation of costs I include depreciation, insurance, rent, fuel, oil, waste, grease, wages, bonuses, repairs and renewals, but no interest on capital.

As regards the lighter form of transport, the private car, char-a-banc and the motor bus, it is difficult to transform passenger service into ton-miles, though as an average about 15 passengers go to the ton. But it may be stated that the present cost of conveying passengers by road by means of motor bus or the char-a-banc varies from 15d. to 24d. a mile, and assuming 16 passengers, an average of two-thirds of a full load (24 passengers) the cost works out at 20d. or 1¼d. a passenger mile. If the weight of the vehicle, 3½ tons, be included as well, then the cost of the ton-mile will be much reduced. In the case of private cars, assuming the average running cost of the moderate powered car without a chauffeur as about 6d. per vehicle mile, at this cost at least four persons can be conveyed, which would mean a cost of about 1½d. per mile per passenger. The cost of larger cars run with paid drivers is now anything between 8d. to 1s. 6d. a mile.

As regards railways, the rise in all outgoings, especially in rates, taxes and labour has been so great of late that it is difficult to give accurate particulars. I am informed on good authority, however, that about 1.6d. per ton-mile was a fair figure till a year ago. But this figure does not include recent rises in costs or labour. The expenses of collection and delivery also in the case of goods not carried in large direct consignments which have also to be added to this 1.6d. so far as the real cost for purposes of comparison between origin and destination has to be ascertained. Two most serious features in railway expenses are the rise in labour and local rates, and British railways will have to pay upwards of

£10,000,000 this year for this latter charge. Owing to this and other causes it is probable that the cost of transport by rail will continue to rise. Indeed, an average of about 2½d. per ton-mile will probably not be an excessive calculation, a figure which would have been thought impossible to charge as an average a few years ago. Considering that this figure only includes the bare cost of transit between station and station, and except very rarely from origin to destination, it is probable that the tendency of all kinds of traffic, except coal, iron and heavy goods in large quantities, to leave the railways and go on to the road will become more pronounced as years go on. Then again, a new, disquieting and expensive feature is the evil of stealing and pilfering which is now a very common complaint, increasing the average cost of freight to the merchant or consignee. It should be remembered that the railway and the ship only convey from fixed points of collection to fixed points of delivery, and not from the point of origin to the ultimate destination. The exact theoretical cost of conveyance is not therefore always the only test by which the trader judges and decides what kind of transport to use.

As regards transport by sea, this is naturally the cheapest of all kinds of transport. There is in this case, like the air, no permanent way to maintain, and the tonnage of goods or number of passengers carried at the same time by the same power and by the same labour is as a rule infinitely greater than by any other means of transport. In the form in which I have been able to obtain the cost of ocean transport, I have had to take into account the gross weight of the steamer besides its contents, for it is almost impossible to give the cost of the conveyance of cargo and passengers apart from the ship with her engines, coal, stores and all equpiment. And as regards the cost of a voyage, this too must include the time and expenditure not only on the voyage, but in ports of call, allowances for delays at destination, as well as for loading, storing and discharging goods and the cost of depreciation and insurance. I have obtained a few typical figures of voyages from London to the East, returning to London. But as the cost per ton-mile by sea is such a small fraction of a penny, the following costs are shown per 100 ton-miles, calculated on the gross weight of the steamer and its contents.

Route.	Cost per 100 ton-miles. Fuel. Pence.	Other items. Pence.	Total. Pence.
London-Australia (via Canal)—			
16 knot mail steamers ...	3·3	3·3	6.6
14 knot intermediates ...	2·4	2·7	5.1
London-Australia (via Cape)—			
Cargo liners	1.6	2.2	3.8
London-Bombay (via Canal)—			
16 knot mail steamers ...	3.8	3·4	7·2
London-Calcutta (via Canal)—			
14 knot intermediates ...	1.4	3.6	5.0
London-Japan (via Canal)—			
12 to 14 knot intermediates ...	2.9	2.9	5.8

The estimated cost, on the other hand, of conveying saloon passengers per ship mile, exclusive of food, but assuming that the whole accommodation for passengers is occupied through the entire journey, is given below:—

Routes (via Canal).	Pence.
London-Australia, mail steamers	1.44
,, intermediate type	1.11
London-Bombay, mail steamers	1.80
London-Calcutta, intermediate type	1.20
London-Japan, intermediate type	1.42

At 1½d. average per passenger per mile and allowing 15 passengers to the ton, then the cost of ton passenger miles is about 22½d. a mile, about the same figure as a motor bus or char-a-banc.

ROUGH ESTIMATED COST OF CARRYING CARGO PER 100 TON-MILES EXCLUSIVE OF LOADING AND DISCHARGING EXPENSES.

	Pence.
London-Australia, mail steamers	10.1
,, intermediate type	8.2
,, cargo liner (via Cape) ...	6.7
London-Bombay, mail steamers type	12.0
London-Calcutta, intermediate type	9.7
London-Japan, intermediate type	9.8

It should be noticed in these statistics that no allowance has been made for interest on capital, which in the case of shipping companies varies from a comparatively low rate which has to be paid on debentures, to a high rate in some cases on ordinary shares where there is not the same security. It is clear from the above figures that the cost of ton-miles by sea is much less for goods than the cost of ton-miles by land, or indeed by any other method of conveyance, so far as can be ascertained at present. But a port, like a railway station, is seldom more than a point of distribution and collection, and I must once more remind you that "origin to destination" should be the ultimate aim and motto of all transport.

In regard to the cost of conveyance by aircraft, I have been in communication with some of the firms who have been conducting recently regular commercial services by airplane and find that their statistics vary a good deal. Lately, at the Air Conference at the Guildhall, Mr. White Smith, whose opinions are entitled to much weight, stated that a machine could be flown between London and Paris at about 38d. per airplane mile. The D.H.18 has lifted and flown with a weight of 2,200lbs., but with a D.H.18 designed purely for goods carrying, and at the reduced speed of 75 miles an hour, the machine would lift probably as much as 2½ tons, or well over 5,500lbs., and the cost per ton-mile would therefore be correspondingly reduced. This figure of 38d. has recently been thought too low and later and perhaps safer calculations place the cost at about 40d. per machine mile. It is clear that in this case there can be no competition with other older methods of conveying heavy goods in bulk. But with passengers, mails and valuable and special freight the outlook is promising. I am inclined myself to think that the cost of airplane transport at the present moment is in the neighbourhood of 44d. per ton-mile, if a reasonable profit is to be included and all risks provided for. At this price the aeroplane can only compete successfully with existing transport because of its speed either over land or sea. As I have said before, speed is a quality which the public are willing to pay for, and speed is the commodity which sellers of air transport will find most saleable.

We now come to airships. In the case of the airship of the large type, which recently flew from Great Britain to America and back, the cost was ascertained to be in the neighbourhood of 23s. 6d. a mile flown. To take the concrete case of England to Cairo and India, and allowing 50 hours for the journey to Cairo and 50 hours on, the expenditure comes out according to Air Commodore E. Maitland at the following figures:—

	s.	d.	
Interest on capital expenditure ...	7	0	per mile over land or sea.
Cost of operating the airships ...	23	5	,, ,, ,,
Cost of running the bases	11	0	,, ,, ,,
	41	5	

Or an "all in" cost of 497d. per mile made good over the ground. If the airship could carry, as a conservative figure, 15 tons of commercial load for a journey occupying 50 hours, this would make the "all in" cost per ton-mile 35½d. for such a journey. Not a formidable figure in comparison with other methods of fast transport.

Allowing seven passengers to the ton, which for practical purposes amounts to each passenger being allowed 1cwt. of luggage free, and one ton of mails at 6d. per oz. for each stage of 50 hours, the following table is of interest:—

	Airship.			Steamer.	
England to	Approximate Time of Transit.	Mails (1 ton carried).	Passengers.	Approximate 1st Class Steamer Passenger Fare.	
Egypt ...	2¾ days	6d. oz.	£50	£45 to £50	Now increased about 20% beyond these figures.
India ...	5 ,,	1s. oz.	£100	£65 to £70	
South Africa	6½ ,,	1s. 3d. oz.	£120	£70	
Australia ...	10½ ,,	2s. oz.	£190	£115 to £128	

The above figures are based on airships actually under construction (R.38 class), showing a profit of 15 per cent., and are based on the carriage of 75 per cent. of the possible passengers.

The passenger ton mileage in this case would work out at about 34d., but no doubt these costs will be reduced later on. And while the cost is in this case moderate, there would be a great saving in time on a non-stop run for at least 2,500 miles—say London to Egypt or 3,800 miles London to India.

TABLE I.

COMPARATIVE AVERAGE SPEEDS BY LAND, SEA AND AIR.

	Miles per hour. Average speed.
Land.	
Express and fast trains	40
Ordinary passenger train	25
Ordinary goods train	14
Motor car or cycle	20
Motor bus or char-a-banc	15
Motor lorry	13
Sea.	
Mail ship	16
Ordinary passenger ship	12
Ordinary cargo ship	10
Air.	
Airplanes for mails and passengers	100
Airplanes for goods	80
Airship for mails and passengers	60
Airship for goods	50

TABLE II.

COST OF TON-MILES BY LAND, SEA AND AIR.

LAND.			
From station to station.			
Per train—Passengers, 15 to ton at 3rd class fare of 2d. a mile	30d.	B	
Goods, average (1919)	1.6d.	B	
From origin to destination.			
Per motor lorry—goods in not less than 3-ton lots ...	10d.	B	
Per bus or char-a-banc—15 passengers to ton	22½d.	B	
Per average motor car	8d.	A	
Per motor cycle	2d.	A	
SEA.			
From port to port.			
Mail ship	.066d. to .072d.	A	Calculated on gross weight of steamer and contents.
Passenger ship (intermediate) ...	.050d. to .058d.	A	
Cargo liners	.038d.	A	
AIR.			
From aerodrome to aerodrome.			
Airplanes for mails and passengers, D.H.18	30d.	A	
Airplanes for goods, D.H.18 (special type)	14d.	A	Estimated.
Airships for mails and passengers, say 10 tons in all ...	36d.	B	
Airships for goods (R.38) ...	35½d.	B	Excluding insurance.
Airplane, 2-engine Vimy type ...	126d. per machine mile.	B	

A weight of vehicle included.
B weight of vehicle not included.

TABLE III.

TRANSPORT IN ORDER OF SPEED.

	Average speed in m.p.h.
1. Airplane for mails and passengers	100
2. ,, goods	80
3. Airships for mails and passengers	60
4. ,, goods	50
5. Express and fast trains	40
6. Ordinary passenger trains	25
7. Motor cars and motor cycles	20*
8. Mail or fast passenger ship	16
9. Motor bus or char-a-banc...	15*
10. Average goods train	14
11. Motor lorry for goods	13*
12. Ordinary passenger ship	12
13. Ordinary cargo ship	10

* The road motor vehicle is the only vehicle which can collect and deliver without intermediate handling between origin and destination.

These figures show that while the cost of ton-miles may in some kinds of transport and for some kinds of freight be a criterion of some value, it is not the only basis of comparison. In other kinds of transport and in the case of freight which has to be collected and distributed in small or comparatively small quantities, it is of little or no value as a guide to either what the public will pay or the traffic will bear. Speed also is an increasingly important factor both in conveyance from origin to destination, as well as from station to station or port to port. Motor transport provides for this, and on long journeys over land or sea by the airship and airplane will equally provide speed. For ascertaining the cost of operating any system of transport, vehicle, train, ship and machine miles divided into the total expenditure will give results in some ways more valuable than ton-miles divided into the total outlay. When, therefore, comparisons are made of various kinds of transport it is first of all necessary, as I have shown, to ascertain exactly what exact services are rendered by the so-called kind of transport, and whether the passengers or freight conveyed demand high speed or special comfort, or conveyance to fixed points only, or to actual destination with no intermediate handling. There can be no question that the public in a country like Great Britain with a number of convenient ports all round the coast and well provided with roads, can with difficulty be forced to pay charges beyond a certain economic figure for railway carriage except for a few special heavy and bulky kinds of goods.

Given free trade in transport, a fair field, and the kind of transport best suited to each kind of trade will win. But air transport will have to fight for its life for some time to come. It is admittedly not yet a cheap form of transport, but it is very speedy, and its main drawback is that at present only short journeys are attempted, such as the cross-Channel, which are not long enough journeys to bring out the advantages of high speed. The net saving of about three to four hours between London and Paris is not sufficiently attractive. But from London to more distant points, such as the Riviera, Italy, Egypt, Algiers, Morocco, and eventually India, are journeys in which the saving of time would be so great as to tempt passengers in a hurry to brave some discomfort, the greatest of which is noise, and to pay a great deal per ton or passenger miles accomplished at say 100 miles an hour. If I were a capitalist or inventor, I would rather have money in a London-Riviera-Algiers-Morocco Transport Co. than in a London to Manchester, Paris, or Brussels Company. There can be no effective competition with conveyance by air on these long distance journeys, and the great saving in time for mails should appeal—though it has not as yet—to the Post Office authorities of every country. And for these long distance journeys I feel sure that the airship rather than the airplane is the best method of transport.

Finally, I may be excused for asking whether the world in general realises the great political as well as economic importance of transport. Lack of roads was and is the sign of a low form of civilisation. It was the most potent cause of the success of the Red Revolution in Russia. It is the chief cause of scarcity and famine in the towns and of isolation in the country districts in Russia to-day. The Government of a country cannot govern or carry on effective administration without passable roads along which troops, people, posts, supplies, and news travel. The greater the transport facilities the easier can social difficulties be ameliorated and overcome. All kinds of transport are necessary for the increasing commerce of the world and air transport will have to bear its share before long in conveying its special kinds of freight. No civilisation can continue to exist without healthy transport conditions, and subsidies and Government control are not healthy symptoms at the moment, and should be got rid of at the earliest possible opportunity. In this, though necessarily brief and condensed lecture on the cost of transport, I have been unable to touch on any but the most prominent features. But the subject is one worthy of concentrated study, and if I have been able to stimulate thought in others I have achieved my object and I hope been able to interest my audience this evening.

DISCUSSION.

The CHAIRMAN said Lord Montagu had clarified many of the vital commercial factors affecting the future of air transport. If he (the Chairman) were right, Lord Montagu's main object in the paper was to show the immediate possibilities and the cost of air transport in the correct sense of proportion to the cost of other forms of transport, and he asked them to look the situation straight in the face. The figures for aircraft appeared very disadvantageous from the commercial point of view, but he wanted to endorse very strongly Lord Montagu's important qualification when he pointed out that exceptional performance, say in the form of speed, while it always entailed additional and exceptional cost, warranted one in assuming that an exceptional price could also be obtained. In Atlantic travel in pre-war days the speed of the "Mauretania" assured a full ship at almost premium rate. To take another example, where speed was not defined, on the German Sud-Amerika Line they gave the most extreme degree of luxury, and that commanded a very big premium, because it was exceptional. He was glad Lord Montagu emphasised so strongly that commercial aviation depended for its ultimate future on its own sound economical performance, with no adventitious aids such as subsidies which were not justified except in the initial stage of the development. They were largely justified there from the national defence point of view, and, in that connection as Chairman of the Advisory Committee, he was naturally gratified that the Government had accepted their recommendation, but infinite harm had been done by the delay of the decision. They owed Lord Montagu a great deal for pointing out a matter which he (the Chairman) thought was new in connection with transport, and that was the changing incidence of labour cost on the cost of the different forms of transport. It deserved very careful consideration by transport authorities, and its importance was very well shown when Lord Montagu definitely suggested that a large proportion of the railway traffic must leave the railways and come on the road. That was a bad look out for the railways, but when one existing way of doing a thing was put hard up against keen competition the scientists and the organiser came in and found a way around it. Perhaps the best example was electric light. That simply helped the gas companies. The gas companies did better than ever. He was rather of opinion that there would be a slight reaction in that tendency, because the very much needed increase of efficiency in the method and process on the railways was absolutely bound to take place. Finally, he would like to say something with more confidence and more optimism on the immediate future of commercial aviation, but it was not very easy. Without doubt the figures of performance of the cross-Channel services during 1920 furnished strong ground—legitimate ground—for optimism, but, unfortunately, the pressure of to-day's financial and industrial conditions handicapped realisation of these immediate possibilities. But they must all be of good cheer, for stability and confidence would be regained in financial and commercial services. When that position was regained they could bring the full weight of public opinion to bear on the new form of transport and encourage the re-awakening of enterprise. The figures in the paper dealing with airships were very hopeful. He would like to ask whether these were merely operating costs or whether allowances were included for the outlay on the sheds and aerodromes, because that was a big factor in connection with airships—the building of the sheds, the interest on the ground and the capital cost of the sheds were a vital factor.

Mr. H. WHITE SMITH said he would like to refer to a figure of his which Lord Montagu quoted as 28d. per aeroplane mile. If he looked at his (Mr. White Smith's) paper he would see the figure was 38d., practically the same as Lord Montagu quoted (44d.). The Lecturer gave for aeroplanes for mails and passengers 30d. He (Mr. White Smith) thought it should be somewhere near 43d.

But perhaps Lord Montagu would be able to explain how he arrived at his figure. In certain cases he had included the weight of the vehicle. For commercial purposes the weight of the vehicle obviously could not be included. The weight of a train could not be included in calculating the cost per ton mile of goods carried. To bring all the costs to a common basis, the weight of the vehicle would have to be cut out in every case. Lord Montagu had very properly emphasised the question of point to point movement of goods and passengers. It would be interesting if calculations could be made as to the cost of handling goods in the form of transhipment in connection with ships, railways and other modes of transport. Even motor transport was not always point to point, strictly speaking. Goods were sent from a warehouse, perhaps by motor vehicles to start with, and then carried on railways and on ships, and at the docks it was handled then by railways again or motor vehicles, and there was a great accumulation of handling charges during transit. If the handling charges were added the ton-mile total would come to substantially more than any of the figures they had put before them. There was the obvious advantage in air carriage that if the goods were kept on the same aircraft the large mass of these handling charges was saved. There would still be the cost of the initial placing of the goods on the aircraft and of taking it off, but not the intermediate transhipment, of which there was so much in the ordinary transport. The true comparison was therefore more favourable to aircraft than appeared at first sight.

Another point that came out was that each form of transport had its own sphere. He doubted whether the air would ever entirely take the place of either of these other kinds of transport. It would be supplementary to them. But in order that it should take its proper place there would have to be considerable reductions in cost. He agreed that speed, which had the effect of saving time and expense, was of great value, and that it must be brought into the calculation in arriving at the cost, but to promote greater use by the public costs would have to be brought down. He agreed with Lord Weir that airship terminal charges were a very important item. There were obvious advantages in the use of airships for very long journeys, but it was rather difficult to see the immediate development of them. The question of finding the capital cost of constructing airships of such design as would enable them to be run commercially was so considerable that, with the financial conditions which seemed likely to obtain for a number of years, it seemed difficult to see where the capital was to come from. The experiments that had been carried on were most useful in showing how far the estimates of cost per ton-mile could be borne out, but it was difficult to see into the future for some years to come. In most of the other forms of transport, whether tramways, motor buses or railways, the costs all seemed to be going up, and they would be handicapped to that extent, as with aircraft the tendency was the other way, and he thought it would continue. The design was improving, the engines were being improved, and he thought in the not far distant future aircraft would be running at costs which were really quite commercial.

Mr. F. HANDLEY PAGE endorsed what had been said in regard to the necessity for air transport to stand on its own results rather than on Government support. If the future of air transport depended on Government subsidy a large financial return could never be expected. If large dividends were earned, and that result was obtained by Government subsidy, there would be an immediate move to abolish the subsidy or nationalise the industry. Eventually, if air transport was going to pay it must depend on running at such a price that its costs were a great deal less than the revenue. The margin of profit, too, must be sufficient to enable canvassers to be employed in selling air transport. As an illustration, if a typewriter were being put on the market, the works cost was only 45 per cent. of the selling price, the remaining cost being that of selling the article. At present one must have canvassers to sell air transport, whether of goods, passengers or mails, and that cost had to be borne in the cost of running the service.

A point that was sometimes overlooked was that service to the public meant more than merely flying from point to point and having a fine machine, beautifully tuned up and an engine running perfectly. It embraced quick delivery of parcels, which entailed such mundane matters as cash-on-delivery. In one case his firm had a parcel which came by air and certain money had to be collected on it. The cheque arrived three or four days later and the consignee wrote saying if that was the quickest way parcels could come by air from the Continent he would have them sent by wheelbarrow in future. The reason for this delay had nothing to do with air transport, but with the ordinary business feature of completing the transaction.

He was amazed to read in that week's "Engineer" an article by a gentleman who called himself "A Pioneer of Aviation," in which he emphasised the view that it was fear of accident when travelling by air that retarded the progress of aviation. That was nonsense. His undertaking had the misfortune of having an accident at the close of last year resulting in the death of some passengers, but it was a remarkable fact that the passengers had not fallen off a bit since that time, allowing for the fact that in the winter there were, naturally, fewer passengers than in the summer.

To make air transport a success, however, the cost of travel must come down, and that could only be achieved by having aeroplanes that could carry greater loads with the same engine power and operate more cheaply by having better standardised machines with fewer working parts and simpler construction all the way through. The time that was now available for investigation of fundamental aero-dynamic processes would probably result in such machines being evolved. The price could then probably be reduced to half or a third of what was charged at present. Success in the reduction of cost depended entirely on the aircraft designer in bringing down the first cost as well as the running cost of the machines.

There was no specific mention in the paper as to the life of an airship. One heard that after the trans-Atlantic trip the large airship used had little life left in it, the rivets being all so badly strained. The depreciation cost depended on the life, and if, as Mr. White Smith said, the capital cost necessary for airships would make their use in the next few years impossible, it seemed that the money spent on experimental airship services could be better given to the aeroplane service, with more immediate profitable result.

Colonel A. OGILVIE thought it was rather difficult to arrive at any figures now with regard to the initial cost of airships, because of the very small numbers of any particular type that had been produced. If true figures of the Zeppelin construction could be got from Germany we might get a different view of the question. There they laid down a dozen or so of the same type and turned them out in a month or so and the initial cost might be a very different thing from our present machines, which were made one at a time and took a year or so to complete.

It seemed to him that there was much more possibility of improving and reducing the running costs in the case of the aeroplane than in that of any other kind of vehicle. The railway costs could not very well be less, and road vehicles had always to contend with the great expense of tyre upkeep, and their engines were not likely to be improved to such an extent that the cost would come down greatly. But there were many more possibilities in the aeroplane which should bring down the cost greatly. He had recently been working on some figures for the resistance of machines at top speed, and the amount of power that appeared to be wasted was remarkable, although he thought the present designs were as good as could be done with the present knowledge. The wings absorbed a great deal more power than they should do or than they would do if reduced in size, and if it were not for the difficulty in landing, the resistance of

the wing might be reduced to a half or a third of what it was at present. One had to compromise between the difficulty of landing and the reduction of the wings, but only a relatively small improvement was wanted there to put a completely different complexion on the matter. A large quantity of power was wasted in pushing the undercarriage along, which was of no use in the air, and an extraordinary percentage of the H.P. went in pushing the fuselage, which was an awkward shape. The proportional resistance of a fuselage and an airship body was about four to one. The airship was four times as good a shape as the other. Such considerations made one think that in a little more time, with a little more research and experiment, the cost of aerial transport would be considerably reduced.

Sir CHARLES BRIGHT said the paper, the first of its kind, was extremely useful and would long remain so, although one hoped the figures would get out of date before long. What was needed to bring aviation to the fore was to focus all their strength on getting it taken up in far-reaching and low populated countries such as Australia, where there were comparatively few railways or good main roads. In cases of this kind aviation should be of immense value for all those concerned in agriculture of one kind or another as well as for business people generally. It should also be invaluable as a means of direct personal communication for diplomatic purposes—in a way that could never be achieved by telegraphy of any description.

Lord MONTAGU, replying to the discussion, said the airship costs included the following costs, as set out by Air-Commodore Sir E. Maitland in a recent paper: The cost of the airship, the cost of the base, the operation of the airship, maintenance, depreciation, the cost of the crew, fuel, running the base, and so on. As stated in his (Lord Montagu's) paper, interest on capital worked out at 7s. per mile made good, the cost of operating the airship at 23s. 5d. per mile and running the bases at 11s. per mile. The life of an airship should be divided into the fabric, the engines and the hull, and the fabric should be sub-divided into the outer cover and the gasbags. The life of the outer cover might be taken as one year, with 2,500 hours flying, the gasbags or ballonets 2½ years, and owing to the fact that airship engines were not run at their full power he also gave them a life of a year, or 2,500 hours flying. They did not know the life of the fabric, except that in the war our airships ran, roughly, three million miles and they had not yet been able to ascertain that they showed any sign of weakness. There was no tiredness of the duralumin, this being due to the fact that there was very little vibration. He apologised to Mr. White Smith regarding the figure of 28d. per airplane mile. That was a printer's error. It should have been 38d. He had to put in the vehicle weights as the shipping people said they could not give the cost without including the weight of the ship. In the paper as he had corrected it he had put A against the figures which included the weight and B against those which did not. He would give the figures of the cost of airship service between England and India. Interest on capital expenditure and reserve fund at 15 per cent. £156,750, or say £157,000, cost of operating airship, as previously stated, 23s. 5d. a mile flown, annual cost of running English base £116,700, running Cairo base £116,700 and running mooring station at Karachi £12,000, making the total £245,000.

In reply to a question as to whether the Zeppelin cost anything like that, the Lecturer said Sir E. Maitland thought that was so, and they must accept him as knowing what he was talking about. These figures were based on airships actually under construction, such as the R.38, and on carrying 75 per cent. of possible passengers, and 15 per cent. profit. Colonel Ogilvie suggested that we had not enough experience to base our calculations on. Our "Blimps" and different airships ran over three million miles during the war with very few accidents, and a good deal was learnt from it.

In reply to the Chairman, the Lecturer agreed that the Zeppelin costs were much lower than our airship costs. When he investigated them some five years ago big Zeppelins cost from £120,000 to £130,000.

A hearty vote of thanks was accorded to the Lecturer on the motion of Mr. WHITE SMITH, who said he had always been a pioneer. One remembered the splendid work he did in connection with the motor car industry, and it was most valuable to have men like Lord Montagu interested in aviation and pleading its cause in the House of Lords and Government circles. The paper would be most helpful to people who were trying to think of aviation commercially.

On the motion of Colonel OGILVIE, seconded by Lord MONTAGU, a vote of thanks was also passed to the Chairman who, in acknowledging the compliment, asked Mr. Handley Page whether he knew anything we were able to do as quickly as we did it in 1913, and the answer was "Yes, talk."

Written contribution from Flight-Lieutenant J. E. M. PRITCHARD: I feel that Mr. Handley Page's contribution to the discussion, especially with regard to his technical statement as to the state of R.34 after her return from the Trans-Atlantic flight, calls for a definite reply.

Before carrying out the flight to New York and back, a distance of over 6,000 miles, R.34 also flew several thousand miles in the course of her preliminary trials, besides carrying out a flight into the Baltic of over 1,200 miles. From the time R.34 was commissioned till her return from America, no special structural or machinery overhauls were carried out, with the exception of the substitution of one new engine in place of an engine which broke down. A short time after R.34 returned from America, she flew from Norfolk to Scotland and again without repairs flew from Scotland to her present station in Yorkshire.

The ship is now in thoroughly good condition, and the only repairs to the structure which it was necessary to carry out cost under £100. These structural damages were almost entirely caused through rough handling while refuelling in America, and not to any strains incurred during the flight. By far the greatest overhauls necessary were those to the machinery installation, the engines in particular. These overhauls were, however, by no means abnormal. In connection with overhauls to machinery, it is interesting to note that airships at present use aeroplane engines. In airships, however, these engines give greater reliability, because they can be run at reduced power.

A large modern rigid airship carries in the order of 16lbs. of useful load per h.p., while it is understood that the average aeroplane only carries in the order of 3lbs. per h.p. Thus, taking the worst view as regards the airship, the machinery items in the airship should only require one-fifth as much overhauling for transporting unit commercial load unit distance as is the case with the average aeroplane.

At present, and I fear for some time to come, any clear conception of the lines along which aerial transport will develop in the future, is unlikely. At the moment, the general public is by no means universally convinced as to the need of aerial transport at all, and those of them who do believe in this form of transport have no clear view as to which type of craft is most suitable. In this unavoidable state of confusion, it is in my opinion most regrettable that Mr. Handley Page, who is admittedly an expert in aeroplane transport, should quote rumours about airships, especially when these rumours do not happen to be true, as, owing to his eminence in aeroplane matters, his opinion with regard to airships would tend to carry a certain amount of weight with the general public.

Structural reliability is, as Mr. Handley Page states, of great importance, and I would like to quote two examples of airship reliability, one of a non-rigid, "C.9," used during the war, the other, the German rigid airship "L.14." (Unfortunately, we have not had sufficient flying in this country yet to wear out a rigid.)

"C.9" was in commission two years 75 days, her time in the air was 2,500 hours, giving a flying average of three hours six minutes per day for the whole life of the airship.

"L.14" was commissioned in August, 1915, carried out a number of raids over this country, and a large amount of patrol work. In 1916 she became, owing to obsolescence, a training ship, and flew more or less continuously till the end of the war. When inspected in Germany soon after the Armistice, this ship, although she had flown regularly during her three years' life, showed no sign of structural degeneration.

With regard to general aerial transport considerations, I would like to point out that the rigid airship has only been seriously recommended for long-distance flights. Although rigid airships have from time to time carried out safely long-distance flights without any special discredit, it has been impossible in this country to carry out regular demonstration flights over a long route for the simple reason that there is no rigid airship base outside this country available for the purpose. I understand, however, from Mr. Handley Page, that there is no such difficulty in the case of aeroplanes, and I would be glad if he would explain why it is that aeroplanes are not now carrying out regular flights between this country and, say, Egypt.

For short-distance flights, however, there is very great doubt as to whether there is any reasonable amount of freight available for aerial transport, and the results obtained on the London to Paris aeroplane service, although this worked with wonderful regularity and punctuality, tend to confirm this view.

In the case of long-distance transport, there is no doubt that the freight will be available for any form of aircraft which can fly with the necessary regularity and safety, if it can cut down the time taken by the existing means of sea transport to one-third. This can, in the opinion of airship experts, readily be done when the necessary base facilities outside this country have been provided, mooring arrangements slightly improved, and certain improvements which are clearly in view in machinery and fabric carried out.

Mr. BERRIMAN (communicated): Lord Montagu's paper deals with the vital economics of transport services. It is a subject on which it is very difficult to acquire accurate information, and the best that can be done is to examine such figures as may be made public from time to time. The most recent were those elicited by the Mansion House Conference, notably in Mr. White Smith's paper, which is referred to in Lord Montagu's text. It is customary to compare transport costs on the basis of 100 per cent. load factor, *i.e.*, that every machine flies its allotted trip every day with a full load. On this basis air transport can be made to show a very favourable return and the main point in any critical analysis is, therefore, to investigate the true nature of the probable load factor and its consequences. It is in this respect that existing commercial air services are at a disadvantage, inasmuch as temporary disablement of the transport unit inevitably represents a high percentage of reduction in the total fleet and, therefore, a considerable diminution in the load factor with a consequent relative increase in the cost of operating the reduced ton miles that remain available. When the number of units in the fleet is large, the temporary disablement of any one unit has a relatively small effect.

As things are at present, it is difficult to recover air ton miles lost by temporary disablement of one or more units. Thus, it is not yet feasible to fly at night nor is it usually practicable to extend much beyond the normal the continuous service of any one machine at the expense of its allotted time off for overhaul. The flying year for air transport is usually reckoned at 300 days, and thus far there is little, if any, evidence in support of an increased estimate. Moreover, it will be found that if an unexpected spell of bad weather should be the cause of abandoning flights during a period that is relied upon as being fine, it will be very difficult to make up the deficiency within the financial year. The effect of

these considerations on the cost of air ton miles is in some degree exaggerated by the limitations of an industry in embyro, and would decrease with development. In order to provide a numerical illustration of the effect of load factor on cost, I submit a table analysing the figure 3s. per ton mile, which was put forward by a member of the Mansion House Conference as appropriate to the London-Paris service. I do not say anything either for or against the accuracy of this figure as such, being merely concerned to show the effect of load factor upon it. I have, however, assumed that it is based on the costs of a daily round trip per machine.

For convenience, the 3s. is reduced to 3.75 pence per lb. for transport from London to Paris on a journey taken as 240 miles. This figure has additional interest also, inasmuch as it gives the cost per passenger mile on the basis of 240lbs. per passenger. The pence can also be read as pounds sterling to give the cost per passenger for this length of journey, viz., 240 miles. The cost is made up in part by overhead expenditure representing so much per day irrespective of the distance flown, and running costs representing so much per mile or rather per trip, because the mileage is determined in advance by the fact that the machine either flies a single trip in the day or a double trip in the day, but it cannot usefully fly a fraction of the journey. This is a most important point because air transport, like other transport, has for its present object to render a commercial service between two or more predetermined places, the mileage between which cannot be altered to suit the convenience of the machine. Some of the figures that were discussed at the Mansion House Conference appear to be misleading because they assessed cost per mile at an indefinite mileage, whereas, in fact, the only figures of any immediate commercial importance are those that are applicable to a particular service under consideration. If the machine flies a double trip in the day, the cost of overheads per trip is halved but the running costs are unaffected by the double journey. For short journeys, several trips may be performed in the day, but so far as the Paris service is concerned, a safe plan at present would appear to be to estimate on the basis of a single trip. Using Mr. White Smith's statistics as an approximate guide for the division of expenditure between overheads and running costs, I have taken the overhead expenditure to be represented by £3 10s. per seat per day, and the running costs by £2 per seat per trip. Thus for half the machines flying and half the available seats occupied (equals quarter total seats occupied) the cost for overheads per day is £14 per seat, but the running expenses are only increased in proportion to the number of *available* seats unoccupied which in this case is one half. Consequently, the running expenses only represent £4 per seat per trip. The total cost per trip for one trip per day is thus £18 on the basis specified. The following table has been prepared on the above mentioned basis of 240lbs. freight being equivalent to one passenger. Taking freights that are equivalent on this basis to a single passenger fare to Paris of 10 guineas, it appears that a load factor of 66 per cent. is the minimum on which the receipts will cover expenditure if the same machine only flies the single trip daily. For the daily round trip, the equivalent figure is less than 50 per cent.

	Single Trip Daily.			Round Trip Daily.		
	A		B	A		B
All machines flying daily and all seats full ...	£5 10	0	5½	£3 15	0	3¾
⅝ " " " " " " " ...	£7 8	0	7½	£4 5	0	4½
¾ " " " " " " " ...	£9 15	0	9¾	£5 7	0	5¾
½ " " " " " " " ...	£11 0	0	11	£7 10	0	7½
⅓ " " " " " " " ...	£17 10	1	5½	£11 5	0	11¼
¼ " " " " ½ " " ...	£18 0	1	6	£11 0	0	11
⅛ " " " " ⅓ " " ...	£27 0	2	3	£16 10	1	4½

A = minimum single fare.
B = equivalent rate per mile for 240 miles and equivalent rate per lb. at 240lbs. per seat.

In Mr. White Smith's paper, the costs were based on hypothetical fleets of six machines. Allowing 2,400lbs. load per machine, it is apparent that such a transport service, if devoted exclusively to goods, would have to find about 1,000 tons per annum at rates equivalent to the above in order to make a commercial success.